Joint Crosswell and Single-Well Seismic Studies of CO_2 Injection in an Oil Reservoir at Lost Hills, California

Roland Gritto, Thomas M. Daley, and Larry R. Myer
Contact: Roland Gritto, 510/486-7118, rgritto@lbl.gov

RESEARCH OBJECTIVES

The objective of this research is to study whether crosswell and single-well seismic techniques can be applied to monitor the sequestration of CO_2 in oil reservoirs. The advantage of injecting CO_2 into oil reservoirs is two-fold: (1) it offers one method of geologic carbon sequestration, while it (2) enhances the recovery of difficult-to-extract oil, which otherwise would remain locked in place.

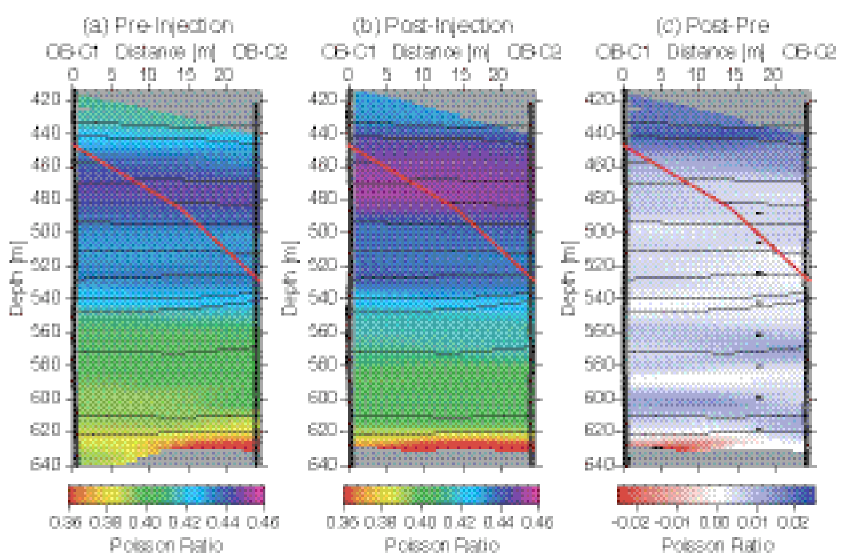

Figure 1. Poisson ratio based on P- and S-wave velocity: (a) pre-injection ratio; (b) post-injection ratio; (c) result of differencing the pre-post injection ratios. The black dashes represent the projection of the CO_2 injection intervals onto the imaging plane, while the red line indicates the location of a fault in the reservoir. The high values in (c) correspond to regions of increased CO_2 concentration spatially correlating with the injection intervals.

APPROACH

The subsurface CO_2 injection program was operated by Chevron USA Production Company in the Lost Hills, California, oil field. We conducted a series of time-lapse seismic crosswell and single-well experiments in a diatomite reservoir to monitor the injection of CO_2 into a hydrofracture zone, based on seismic P- and S-wave data collected during pre- and post-CO_2 injection phases. Tomographic images of the differences in P- and S-wave velocities were constructed, because the differencing of the data sets is particularly sensitive to time-lapse changes in the reservoir. Estimates of Poisson ratio were then calculated from the velocities to determine the state of the CO_2 in the reservoir.

Figure 1 shows three tomographic cross sections of Poisson ratio before and after injection, as well as a difference image of the two. The pre- and post-injection tomograms show the stratification and compaction of the reservoir rock with depth (decreasing Poisson values). The difference tomogram shows an increase in Poison ratio throughout the imaged area, indicating an increase in pressure in the reservoir. This information, in conjunction with the P- and S-wave results, led to the conclusion that the injected CO_2 dissolved into the liquid phase, which was corroborated by *in situ* pressure measurements and reservoir simulations. The seismic single-well supported the crosswell results.

ACCOMPLISHMENTS

The experiment has shown that seismic crosswell time-lapse P- and S-wave data can be used to successfully monitor CO_2 injection and migration in oil reservoirs, and to determine the state of the injected gas. Single-well seismic measurements provide independent data that are useful in corroborating crosswell results without adding much data acquisition time in the field.

SIGNIFICANCE OF FINDINGS

The analysis of the CO_2 injection experiment revealed that both P-and S-wave data sets are essential in determining the migration and state of the injected gas in the reservoir, because one data set by itself would yield inconclusive results. The availability of time-lapse data reduces the effect of reservoir heterogeneity, which would be difficult to estimate in an absolute sense. Poisson ratio can be applied to determine whether the injected gas has dissolved into the liquid phase or remained in gas form. It also appears that seismic crosswell data are useful in delineating the structural features of the reservoir, whereas single-well seismic data are applicable in determining the location and possibly the properties of a hydrofracture zone.

ACKNOWLEDGMENTS

This work was supported by the Assistant Secretary for Fossil Energy, Office of Coal and Power Systems and the Office of Natural Gas and Petroleum Technology, through the National Energy Technology Laboratory (NETL), of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. Support was also provided by Chevron USA Production Co. and the National Petroleum Office under Contract No. DE-FC22-95BC14938, Class III Field Demonstration Project.